ELECTRON-ION COLLIDER DETECTOR ADVISORY COMMITTEE

Report of the 12th Meeting held at BNL, 26 – 27 January, 2017

BNL, in association with Jefferson Laboratory and the DOE Office of Nuclear Physics, has established a generic detector R&D program to address the scientific requirements for measurements at a future Electron Ion Collider (EIC). The primary goals of this program are to develop detector concepts and technologies that are suited to experiments in an EIC environment, and to help ensure that the techniques and resources for implementing these technologies are well established within the EIC user community.

The EIC Detector Advisory Committee meets twice a year, typically in January and in June. The current Committee members are: M. Demarteau (ANL/Chair), C. Haber (LBNL), P. Krizan (Ljubljana University/J. Stefan Institute), I. Shipsey (Oxford University), R. Van Berg (U. Pennsylvania), J. Va'vra (SLAC) and G. Young (JLab). Regretfully, Jerry Va'vra was unable to join the meeting in person but participated remotely. During the January meeting progress reports are reviewed and feedback is provided to the proponents. During the June meeting both progress reports and new proposals are reviewed. Funding recommendations for continuation of existing and for new proposals are provided by the Advisory Committee to the program manager in advance of the fiscal year funding cycle.

The EIC Detector Advisory Committee met at Brookhaven on January 26 and 27, 2017 to hear status reports of the eleven funded projects and also a Letter of Intent on a GEM based transition radiation tracker. Progress reports and the LOI were submitted before the meeting and evaluated by the committee. The committee thanks all the collaborations for their excellent presentations and status reports and are to be commended for their progress. The increase in the number of publications is especially welcomed and all proponents are strongly encouraged to continue to publish their results, preferably in peer-reviewed journals.

Special mention is due to the eRD2 collaboration studying magnetic cloaking, which has concluded its highly impactful research program that has the potential to be beneficial for a very broad community. This collaboration has engaged 24 undergraduate students, two graduate students and one high school student in their research program that included field tests at different national laboratories. Providing this unique experience in science, technology, engineering and mathematics (STEM) is highly valued and appreciated. It is of immense value to the field.

General Remarks

The DOE has initiated a $7M program for accelerator R&D shared between various national laboratories. It is recognized in the 2015 NSAC Long Range Plan that U.S. leadership in nuclear physics requires tools and techniques that are state-of-the-art or beyond. Although vigorous targeted detector R&D for the Electron Ion Collider is recommended to ensure that this exciting scientific opportunity can be fully realized, regretfully no commitment to support detector R&D

has been realized yet. To brief the Office of Nuclear Physics in the Office of Science on the status of the detector R&D being carried out in this framework, Thomas Ullrich, Abhay Deshpande and Marcel Demarteau visited the office on November 22, 2016, representing the program management, the EIC users group and the EIC R&D Advisory Committee, respectively. The accomplishments of this program and its impact were presented and put in historical perspective comparing it to the funding received when RHIC was proposed. A ramp-up to a funding level of $4M per year within four years was recommended. The Office appreciated the visit, which they found very informative and their response was very positive. Funding, however, especially with a change in administration, is unknown. The PIs of the projects are encouraged to regularly contact their program managers and keep them abreast of the progress made within the context of this program.

The committee anticipated that, with the endorsement of the EIC as the next highest priority project for new construction for the nuclear physics community and the support for advanced technology R&D, there would be a substantial increase in the number of proposals to be considered while the funding was not expected to increase. This prediction came true at the last meeting, which was particularly challenging because the funding request exceeded the available funding by more than a factor of 2.5, exacerbated by the fact that part of the allocated money was not available due to prior hiring commitments. Very cognizant of the funding constraints, interest shown by new international collaborators, and the desire to keep the emphasis of this program on research rather than development, the committee took a purposeful approach with respect to the funding recommendation. The proposals were subdivided and then priority ranked by the committee. Only those elements of the proposals that were considered high priority were recommended. This resulted in some significant cuts to several existing programs. Despite these cuts, there has been good progress and the committee is very appreciative of all effort expended to retain the momentum of existing R&D programs under difficult funding conditions. Some of the collaborations did express their concern before the Advisory Committee meeting about sustained viability of their efforts following the advice of this committee at the previous meeting and the persistent limited availability of funding. To address these concerns the committee held an open session to provide the proponents an avenue to voice their concerns and suggests potential methods for improvement. The committee also met in private with the eRD3 and eRD6 consortia together. These dialogues were very constructive and much welcomed. Taking into account the feedback from the collaborations, the following procedure is proposed to increase the effectiveness of the overall program while at the same time optimizing the use of the limited funding.

Given that the funding situation is not going to improve in the near future, the committee is of the opinion that a more focused R&D program, with fewer projects, but each with a larger funding base, provides for a more favorable path to quickly increase the overall funding for this R&D program. New proposals therefore are asked to provide a research program with a deliberate schedule for yearly deliverables. Each proposal should also consider three budget scenarios and articulate deliverables under each scenario: a nominal, baseline budget, a nominal budget minus 20%, and a nominal budget minus 40%. Besides the deliverables, a clear set of intermediate milestones should be presented under each budget scenario. All proposals should also clearly indicate how the EIC science will benefit from the R&D. Furthermore, a "money matrix" itemizing the budget allocations to the individual institutions and the area of research would be very helpful in the review process.

In DOE parlance, mission need is referred to as CD-0. With the National Academy Review ongoing, it will be at least another three years before the EIC project will receive CD-0/1. Until then, the focus of this R&D program is generic R&D or directed R&D. Generic R&D in this context refers to concept-independent research, developing a new technology or advancing an existing technology to such a level that it will satisfy the requirements of an EIC. Directed R&D refers to research and development of an area that has been identified as an area where current state-of-the-art is not able to meet the EIC physics requirements or where a technology is completely missing or unaffordable. The committee has noticed that some of the existing proposals are moving more in the direction of pre-construction engineering design (PED), which seems to be referred to as "targeted R&D". This falls outside the scope of this program. The intent of this R&D program is to support generic and directed R&D as described earlier. When a concept has demonstrated proof-of-principle and has reached a level of maturity where scaling by a factor of a few is involved, this research has reached a level of maturity where it has satisfied the goals of the R&D program, can be moved out of the program and be easily revived once calls for concept detectors are issued and project R&D funding can be obtained.

Post-docs are an extremely valuable resource to accomplish the research goals. At the same time, post-docs are a long-term commitment and a long-term financial obligation to the program. The committee reiterates its position that extended postdoc terms working solely on instrumentation are (unfortunately) not a good career path for postdocs. We would also like to emphasize that postdoc support does not automatically transfer from one postdoc to a new postdoc. Moving forward, postdocs can be supported at the 100% level for at most two years. Only under exceptional circumstances will a postdoc be funded for an additional year, but at most at the 50% level. Other funding will have to be identified for the third year to facilitate transition to other sources of funding and provide a pathway for the postdoc to move into another position.

As noted in several previous reports, this program should be regarded as initiation funding for research that is able to obtain independent base funding. If there exist extenuating circumstances we expect the PIs to contact the program manager, Thomas Ullrich, well in advance to discuss possible transition and mitigation strategies.

The EIC will most likely have CD-1 or CD-2 status within the next five years. This time scale is a near-perfect match for proposals to be submitted to the DOE sponsored Early Career Award Program (https://science.energy.gov/early-career/). We strongly encourage junior U.S. faculty to take advantage of this program. Given the high priority of the EIC within the Office of Nuclear Physics, proposals with an instrumentation element that enables a key goal of the EIC physics program should be very well received. We also note the NSF Faculty Early Career Development (CAREER) Program that is available to the university community (https://www.nsf.gov/career).

LOI: GEM based transition radiation tracker

Y. Furletova reporting

The committee thanks the proponents for their Letter of Intent to study a GEM-based transition radiation tracker in an EIC detector to aid in electron identification. The proposal calls for GEANT4 simulations of a TRD setup with GEM detectors to evaluate the e/pi rejection factor for different configurations; using the existing facility at JLAB Hall-D to perform a test of various radiators; and to test different Xe-gas mixtures. The Committee would be interested in a further discussion of e/pi rejection needs of a detector as a function of rapidity.

Recommendation:
This proposal targets an important area of research for the EIC, where particle identification will play a major role. The proponents are encouraged to strengthen the motivation for a GEM-based transition radiation tracker for an EIC detector through simulations. The added physics reach and pion rejection within a full EIC detector simulation, with other particle identification technologies and tools already included, should be quantified at the time of submission of the full proposal.

eRD1: EIC Calorimetry

O. Tsai and C. Woody reporting

Tungsten-fiber calorimeter development

The Committee takes note that the fiber-tungsten EM Calorimeter development has now led to working prototypes with good energy and position resolution, a choice of readout technology, all coupled with levels of radiation hardness that would result in a capable EM calorimeter for the barrel and hadron-going directions at an EIC. The collaboration is congratulated on this achievement. One could remark that the concepts developed to date are ready to be incorporated into the design for an EIC detector. That said, there is still room for improving performance, as reported by the eRD-1 collaboration.

The Committee also takes note of the recent measurements of light-collection from the tungsten-powder test calorimeters and the efforts to improve the light collection uniformity via work on fiber placement and routing as well as the work on coupling of readout devices such as SiPMs to the fiber-tungsten matrix. The study of light-guide geometry and the trade-off between radial compactness, which favors short guides, and uniformity of response, which favors long ones, is important to clarify on the way to establishing a final design. This will be furthered by the upcoming tests of the recent prototypes in STAR in the coming RHIC run, in particular of the triply-instrumented device with PMT on one end and stacked SiPMs on the other, which allows one layer of SiPM to sense only penetrating charged particles and quantify that contribution to the performance. The recent manufacturing advances in prototypes for sPHENIX are of interest, and the Committee looks forward to further test results of these devices including angle-of-incidence studies. The position resolution and resulting limits on the ability to separate photons from neutral-pion decays are also of interest.

The collaboration has also continued their measurement of the effects of radiation exposure to the long-term performance of SiPMs. It was not clear to the committee if the radiation damage tests were carried out with the right neutrons. Because scintillating fibers have a lot of hydrogen, neutrons will be thermalized more efficiently, are captured, and perhaps could damage SiPMs more readily than fast neutrons. If the tests were carried out with neutrons from fission reactions, the effective neutron temperature would be too high. A Geant4 simulation to estimate the flux of thermal neutrons and the total flux of thermal neutrons coming from the calorimeter would be very useful to have and is suggested. It would also be of interest to know if any studies of annealing of the damage or of compensating it by operating at reduced temperature are planned. The demonstration of the minor effect of expected level of radiation exposure on SiPM component materials is a nice addition.

The Committee would like to see the studies carried out on light collection uniformity and methods to improve it. This program will then have reached a good point to wrap up its efforts for this phase of the R&D.

Crystal calorimeter development

The Committee takes note of the ongoing effort to characterize lead-tungstate crystals from Crytur and SIC and recognizes the need to qualify a vendor in order to be able to propose a high-resolution scintillating crystal EMCal for the EIC. The group has established required values for light yield, uniformity and radiation resistance for such a crystal-based EMCal at the EIC and is actively pursuing measurements to determine if presently-produced crystals meet them. The measured results are now at a level to provide useful feedback to potential vendors.

It would be helpful in a future report to have a compact recapitulation of the program of needed measurements to qualify a crystal, the apparatus needed for the various required measurements and what of this equipment is available now to the collaboration vs. what is still needed, and the plan for establishing any remaining needed capabilities in measurement, taking into account the tight budget constraints. It is recognized that this capability will need to be available to the community for the long-term during any production of a crystal-based EMCal for the EIC.

The Committee also takes note of the several institutions involved, the various sources of crystals including those being produced for detectors to be used outside of the EIC, and the interactions with the two commercial vendors, and congratulates the collaboration for organizing all this.

The importance of achieving a small constant term in the normalized resolution was stressed by the collaboration and studied in simulation results reported. It would be of interest to see further analysis of contributions expected to this limiting behavior, including uniformity of response, calibration precision among different towers, rear leakage of showers, dependence on angle of incidence, and the amount of allowable dead zone between towers. For future reference it would be useful to have an understanding of the proposed size of a tower, notably the number of radiation lengths, as well as shape of a tower. The collaboration mentioned a trapezoidal longitudinal shape to improve uniformity of response; the related efforts on the L3 BGO calorimeter for LEP could be of interest here.

If an adequate number of crystals can be obtained, it would be of interest to see a plan for a test beam program that included establishing the limiting energy and position resolution. The Committee looks forward to the future reports of the collaboration and their plan to address the issues noted above.

The need for very high resolution ($30\%/\sqrt{E}$) hadronic calorimetry for the extreme forward region was mentioned. This requirement exceeds the current limits of the technology and would require significant investment. If the collaboration intends to propose a research program to achieve these resolutions in the near future, it needs to be very clearly demonstrated what physics program will require this level of resolution.

eRD2: Magnetic Field Cloaking Device

N. Feege reporting

The collaboration has demonstrated successful shielding of an external magnetic field of up to 0.5T using a multi-layer superconducting shield coupled with a ferromagnetic outer shell as laid out in the original proposal submitted. This device could find an interesting use as a compact method to shield the EIC circulating beams from the field of a dipole magnet used in the forward spectrometers at the EIC.

Earlier reports from the collaboration established scaling rules with number of superconducting shield layers, type of superconductor used and operating temperature. A nice development has been to demonstrate that newly-available cable made of high-temperature superconductor can be used and operated at liquid nitrogen temperature, which greatly simplifies the cooling and any associated cryostat for such a device. A parallel development established a method of building the required ferromagnetic shield using a cast-epoxy method that allowed control of the shield's magnetic permeability.

There is an observation of a slow degradation of the shielding as a function of time once a certain level of external field, perhaps a threshold field, is reached. This might be a subject of future study.

The collaboration is to be congratulated for the large number of students, in particular undergraduates, who have been involved in this project and have gained their first exposure to the labs at Stony Brook, Brookhaven and/or Argonne.

The generic R&D component of this research program has now come to a successful conclusion and the collaboration is to be congratulated for this. Given the relevance of this R&D for the research and accelerator communities at large, the collaboration is strongly encouraged to apply for follow-up funding to take this research to the next level, possibly of a demonstration in a real beam environment.

eRD3: Fast and lightweight EIC integrated tracking system

M. Posik reporting

Significant progress has been made on scanner, rings and assembly infrastructure for triple GEMs at Temple University. The group is working towards assembly and testing of 40 cm scale devices using largely commercially produced components. The plan going forward, "targeted R&D" on the GEM program, is aimed at an "EIC common foil" meter-scale forward chamber in collaboration with eRD6.

Progress has been made on MicroMegas (MM) performance testing and implementing a DREAM chip readout to replace the no longer available APV device. The resistive technology looks promising; the lack of obvious sparking is very encouraging. The future program on the MM side is aimed at testing of the barrel detector being assembled in FY17.

The 2017 International MPGD conference in conjunction with an RD51 collaboration meeting will be held at Temple University in May. The conference is being organized by the members of the eRD3 and eRD6 collaborations and gives the EIC large visibility.

As noted in the introduction, the EIC R&D program is intended to support either "generic" or "directed" R&D but not detailed pre-construction design appropriate for an actual detector (PED) that is required when a project is at the CD-1/2 stage. As both the GEM and MicroMegas efforts seem to have demonstrated significant successes, the future work in this area needs to be focused on remaining MM or GEM detector questions that might expand the physics reach or reduce the implementation risk. Given the by now greatly increased confidence in GEM and MM detectors for the expected physics measurements, the committee would like to understand in some detail the severity of the risks for a future EIC detector that are expected to be retired by the work planned for the next funding cycle. Some of the proposed efforts (e.g. additional work on the DREAM based readout beyond that needed for the first prototype readouts) seem out of place and all future efforts will need a strong motivation given the present scarcity of funding.

Recommendation:
Given the scope of the research programs, the eRD3 and eRD6 collaborations are encouraged to critically self-examine their research programs within the context of the highly funding-constrained EIC detector R&D program, and propose a reformulated targeted research program fitting the current EIC detector R&D framework addressing the urgent EIC needs in the areas of tracking and PID.

eRD6: Tracking Consortium for the EIC

K. Dehmelt reporting

eRD6 covers a wide range of tracking and PID efforts at six different institutions. The TPC/Cherenkov prototype test beam results are quite impressive but whether such a device is a good candidate for an EIC detector is not fully clear. The zig-zag pad readout efforts show significant progress but may be running up against technical limitations in printed circuit manufacturing processes. Whether further progress is needed here should be discussed in the context of specific benefit to EIC science from improved detector performance. The consortium has also produced a common GEM foil design, in concert with eRD3, that has a number of innovations that will benefit detector assembly and system integration. The zebra contact scheme is especially interesting.

Work was also done on removing the Cu layer on a standard GEM foil to reduce the material budget. Unfortunately, no simulations or full material budgets have been presented so it is difficult to know if the reduction in material is significant; on the other hand, the ablation of the very thin Cr layer in use is a clear problem. The proposed compromise of having Cr GEMs for only the first two of three layers may work but the material win would be even less. A literature search might have been helpful prior to the tests. In any event, the very thin Cr layer is likely to remain a risk over the long term and use of the technique should be more strongly motivated. The collaboration is requested to show the impact of the switch to Cr layers in global tracking through simulations of one of the existing concept detectors.

The MicroMegas work is largely directed at a possible RICH detector but has some synergies with the other tracking efforts. In addition to the MM work there is also a strong program to construct thin mirrors suitable for short wavelength Cherenkov light.

As noted in the introduction, the EIC R&D program is intended to support either "generic" or "directed" R&D but not the detailed pre-construction design appropriate for an actual detector (PED) that is required when a project is at the CD-1/2 stage. Some of the work of the consortium appears to be heading towards a more detailed design of some final detector rather than a more generic effort targeted at specific EIC challenges. Detailed engineering questions such as how to deal with somewhat larger devices or optimize important but not vital parameters do not seem pertinent enough at this stage of the project given the funding situation and the clear need for R&D in other principal EIC technology areas. In the future it will be important to strongly motivate the proposed R&D work ("generic" or "directed") in terms of increased EIC physics reach or greatly reduced technical risk given the very tight fiscal constraints.

It is noted that the eRD3 and eRD6 collaborations have expressed an interest at the last meeting to consolidate their research programs and that at the last meeting the eRD6 collaboration grew with the addition of new international collaborators.

Recommendation:
Given the scope of the research programs, the eRD3 and eRD6 collaborations are encouraged to critically self-examine their research programs within the context of highly funding-constrained EIC detector R&D program, and propose a reformulated targeted research program fitting the

current EIC detector R&D framework addressing the urgent EIC needs in the areas of tracking and PID.

eRD14: Integrated particle identification for a future EIC

P. Nadel-Turonski reporting

The eRD14 consortium studies particle identification for the EIC in four focus areas: a dual-radiator RICH (dRICH) for the hadron endcap, a high-performance DIRC for the barrel, a modular aerogel RICH (mRICH) for the electron endcap, and a high-resolution mRPC TOF system. There are in addition three technical areas of R&D being the study of large-area photodetectors, performance of photodetectors in high magnetic fields and the development of electronics.

At this review, a clear presentation was made of the hadron PID requirements, and good progress was reported on most of the items.

Dual-radiator RICH

An acrylic window has been added to separate the aerogel and gas radiators so that the two volumes are not in contact and low wavelength photons from aerogel (likely Rayleigh scattered in the aerogel) are filtered out. The plan is to implement in the simulation a compact eRICH compatible version, and to optimize the reconstruction algorithms. An evaluation of the performance using the current parameters for the magnetic field is also proposed, as is a study of possible light sensors.

Recommendation:

It is recommended that the specifications for the photon detector be defined within the next half a year.

<u>DIRC</u>

The combined effort with the PANDA DIRC group helped to test several counter geometries. The measured single photon resolution agrees well with the simulated response. This proves that the MC simulation is accurate enough to be used for predicting the performance in various optical designs. While the lenses were studied for their optical properties, the question of radiation hardness of the three-layer-lenses still needs to be addressed. The committee notes that the use of small plates, say with sizes of 2”x2”x1/8” or even smaller, is a most cost-effective way of carrying out these studies and analyzing them with a monochromator. Similarly, glue samples can be tested by placing them between radiation-hard small Suprasil quartz plates, and testing them the same way after curing.

Recommendation:

It is highly recommended to finish the irradiation tests of the 3-lens optics, lenses and glues, preferably by using smaller size material samples, a ^{60}Co source and a monochromator.

Aerogel RICH (mRICH)

The test beam results have been prepared for publication. While the number of detected photons agrees with expectations, the Cherenkov resolution comparison cannot be made because of a non-optimal focal length of the Fresnel lens and too coarse photo-sensor granularity. A next iteration is needed for a proof-of-principle. Also, the lens has to be tested for radiation hardness.

Recommendation:
The committee would like to see a prioritization of the various PID methods being pursued and recognizes the need for a proof-of-principle of the detector, and clear conclusion from the radiation tests of the lens.

TOF Detectors
MC studies were carried out to show that with a single track TOF resolution of 10ps a starting time (t_0) resolution of 7ps can be achieved with two tracks in the TOF detector acceptance. A test of the algorithm on real data (e.g. ATLAS) would be an excellent way to verify the performance - ATLAS has a much worse t_0 resolution.

Recommendation:
Try to test the algorithm on real data; it would be good to see test beam results with a 4-channel DRS4 digitizer, while all other pads are terminated.

Sensors for high magnetic fields
Gain measurements were carried out of commercially available multi-anode MCP-PMTs in high magnetic fields. For the LAPPDs, a new HV divider was designed, and 10 individual MCP-PMTs were manufactured. High rate tests do not seem to agree with Lehmann's studies of MCP-PMTs for PANDA; is this due to a much higher gain operation in LAPPDs? The committee supports the simulation effort of all older tubes and also tubes the consortium intends to buy, but would like to reiterate that it would like to see the results of the simulation before new tubes are being bought.

Recommendation:
The committee would like to see a clarification of the differences in the high rate behavior of different tubes.

Electronics
The consortium is developing a strategy to provide photo-sensors for future R&D needs to reduce cost and maximize synergies. The plan will be presented in the FY18 funding proposal, involving the INFN group; the proposal will take into account benefits from the experience of the University of Hawaii group with the electronics for the Belle-II TOP DIRC and KLM detectors.

eRD15: Compton Polarimetry

A. Camsonne reporting

At the summer 2016 meeting the Committee recommended funding for eRD15 to support simulation and beam studies, but advised that work on electronics and specific chamber design should be reduced. At this meeting, excellent progress was reported on simulation of the Compton asymmetry, electron rates, synchrotron radiation effects, and studies of wakefield higher order modes. Itemized and detailed deliverables were described and the Committee notes that this work is well advanced. The Committee enthusiastically supports the continuation of this work and the funding of a post-doc who remains engaged here.

The project also reported progress on an electronics test stand. The purpose of this test stand was to study fast detectors which would meet the specifications of the instrument. While this is reported as a FY17 deliverable, and indeed good progress was shown, the Committee, however, cannot support continued large purchases of equipment to extend this to a full efficiency measurement. A preliminary funding request was shown for next fiscal year. As previously recommended, we expect the project to focus the resources supported by the EIC Detector R&D program, on the important, and successful work on simulation and higher order beam studies. The research for faster detector readout and the development of a test stand seem to be very well matched to a JLab supported LDRD proposal and the proponents are encouraged to pursue that route.

Recommendation:

With regard to the shown funding request for next fiscal year, it is noted that funding for the postdoc, travel, and CST license are looked upon favorably for support at the requested level. The work on amplifiers, discriminators, and hardware for detector tests are not regarded as high priority research areas in a limited funding environment. Exploring LDRD funding for this part of the research program is recommended.

eRD16: Forward Silicon Tracking

E. Sichtermann reporting

Interest in the development of silicon tracking for the EIC was first introduced to the Committee in 2015. At that time there were two focuses – one on simulation and layout, and one on technical issues such as interconnections and aluminum conductors. The Committee has stated, and reaffirms here, that it looks very favorably on work in the area of Si tracking for the EIC. The Committee remains supportive and sees this as an important area and important new development.

We note that the focus has narrowed, at present, to simulation and layout studies. In this regard we are glad to see studies underway to optimize the layout, dimensions, and positions of disc layers, and comparisons with barrel designs. The results presented were a bit confusing however. Different results are to be expected from analytical calculations, single track studies, and full multi-track simulations. It would be good to clarify and tease out the effects among these. For example, with regard to single track performance, one would expect the momentum resolution of 6 spaced discs and 3 groups of 2 discs to be similar, as long as the tracking length and position resolution are the same. On the other hand, mis-tracking, and pattern recognition aspects could be very different in a busy environment depending upon the disc positions and groupings. Furthermore, any eventual fast tracking application (trigger?) could benefit, or not, depending upon the layer groupings and positions. The Committee hopes that these performance and layout studies will continue and progress.

Taking into account the Berkeley group's technical strengths in electrical and mechanical engineering, the Committee looks forward to future activities in this area.

Since 2016, we have also seen the appearance of new groups with interest in Si tracking. In particular, the Birmingham group has entered with particular interest in central tracking and sensor and electronics technology. The Committee already noted the potential synergy and complementarity of the Berkeley and Birmingham efforts. We stated this in the past but now want to restate this with great clarity – we hope that the Berkeley forward tracking and technical efforts, and the Birmingham efforts on central tracking and sensor and electronics will merge and form a productive collaboration.

As an aside, we don't see the relevance of the ALPIDE sensor, at this time. The tracking studies should specify what it needs. Hopefully the appropriate sensor can be found or developed (in collaboration with eRD18).

Recommendation:

To repeat and underscore the observation from the July 2016 Report, the Committee notes the potential synergy and complementarity of the Berkeley and Birmingham efforts. It is hoped that the Berkeley forward tracking and technical efforts, and the Birmingham efforts on central tracking and sensor and electronics will merge and form a productive collaboration.

eRD17: BeAGLE

M. Baker reporting

This work on an eA DIS event generator, BeAGLE (formerly called DPMJetHybrid), including nuclear shadowing & parton saturation, is essential in establishing EIC detector requirements.

The Progress Report describes detailed work involving a good understanding of the nuclear physics aspects and of non-perturbative phenomena. The progress is neatly summarized in the Table on page 2. This reporting format is appreciated by the committee. The scope and the manpower seem realistic.

The proponents have implemented multi-nucleon shadowing at low- x in about as realistic a manner as one can expect given current understanding. *This achieves the main technical goal of eRD17.* The proponents have corrected some deficiencies involving assumptions that the target remnant is a proton- when it could be a neutron. They have accounted for the fact that EIC will be a collider rather than a fixed target experiment.

The statement is made that BeAGLE has 'over-excited' the nucleus. This sounds potentially serious but the authors seem confident that they can easily fix it. The outline for future work and manpower on it seem realistic, but as the proponents state there can always be unforeseen difficulties. In particular, line 11 of the Table hides potential challenges since it involves the role of diffractive processes as A increases. This will need better data- the data from the EIC itself to sort out, hence elements of this work will be an ongoing project for a considerable time.

Baker and Zheng are also part of JLAB LDRD "Geometry Tagging for JLEIC". The main thrust of that project is to implement two EIC R&D simulation programs (eRD17-BeAGLE and RD-2012-5-Satre) at JLAB and use them to help validate and improve the forward detector/IR design for eA collisions at a JLEIC. The work focuses on complete final state reconstruction, cold nuclear matter effects, code installation & integration at JLAB, and physics at JLEIC energies.

Recommendation:
BeAGLE will be a valuable tool for studying forward detector requirements. It is to be used soon at both BNL & JLAB thereby achieving the main strategic goal of eRD17. The proponents are encouraged to continue their highly relevant work to ensure on-time completion, taking advantage of the fact that all principal players are now geographically in the same location.

eRD18: Precision Central Silicon Tracking & Vertexing for the EIC

P. Jones reporting

The proponents seek to develop a detailed concept for a central silicon vertex detector for a future EIC experiment, exploring the potential advantages of HV/HR-CMOS MAPS technologies.

Silicon tracking and vertexing technology has the potential to significantly enhance the physics capability of a detector for the EIC. Silicon technology is an area, which is relatively new to the EIC R&D program and is growing quickly. To realize that potential, and as there is a great deal of synergy between eRD16 (forward silicon tracker) and eRD18 (central silicon tracker), the committee strongly encourages the two groups to coordinate efforts and seek ways to collaborate. The committee looks forward to hearing about progress on coordination and collaboration at its July meeting.

There is a significant international program to develop radiation hard thinned small area deep depletion pixel monolithic sensors as they have broad applicability to the physics program of a range of future facilities from electron positron and pp colliders to the EIC. The eRD18 proponents are part of this international program and bring their expertise to the EIC instrumentation development program.

The proponents seek to demonstrate the possibility to achieve higher spatial resolution and faster charge collection in a large depleted sensor volume. The R&D strategy is to investigate two commercial HV/HR-CMOS technologies to explore configurations of collection electrode, and pixel size. The starting point is the ALICE ITS ALPIDE chip.

One of the original goals has been abandoned as not workable, moving the junction for the substrate contact to the epitaxial layer; an alternative using multiple sense diodes is discussed.

The group have secured access to LFoundry process information so can start TCAD work, which is good. They have access to RD50 parts, which is also good. The group has also identified a candidate post-doc to be appointed.

In summary the group has been establishing routes to submit designs and get parts and that seems to be going well. As this is the major part of the WP1 goals for this period, the committee view the progress positively.

Recommendation:
To repeat and underscore the observation from the July 2016 Report, the Committee notes the potential synergy and complementarity of the Berkeley and Birmingham efforts. It is hoped that the Berkeley forward tracking and technical efforts, and the Birmingham efforts on central tracking and sensor and electronics will merge and form a productive collaboration.

eRD19: Machine Background Simulation

R. Petti reporting

The results were shown of the first set of studies. While they are interesting, more accurate material description of the beam elements and detector are needed for meaningful estimates of rates in the detector volume.

Recommendation
The group is encouraged to intensify their efforts on the synchrotron radiation studies, to include material description and secondary interactions.

eRD20: Software Development

Markus Diefenthaler reporting

The proponents are focusing their efforts on the developments of analysis environments. The goals for the current year are to explore Interfaces and integration of existing frameworks and toolkits; plan for the integration of new computing infrastructure and new computing standards; build an active user support group that fosters collaboration. The group has made good progress on implementing radiative effects and are in the process of verifying the code. They are also collaborating with the authors of BeAGLE and are working towards a common geometry and detector interface. A workshop has been held in October to review existing options of software frameworks for adoption for an EIC software environment and a second workshop is planned for next month. The group has reached out to the Geant4 group to validate the physics in the energy regime of the EIC. A new file format (EicMC) has been adopted for file format based on Google protocol buffers and the HEPsim repository will be used for file storage.

Recommendation:
The committee suggest the group investigates the required event size and data size to evaluate the EIC computing needs. The open, broad approach the collaboration is taking to develop the software infrastructure for the EIC is welcomed. The group is urged to be cognizant of existing, well-supported efforts that can be deployed for the EIC to ensure optimal use of existing resources.